

Growth Evolution of GaN on GaP (001) Substrate by Metalorganic Vapor Phase Epitaxy

D. S. Wu^{*}, W. T. Lin, C. C. Pan, R. H. Horng¹ and C. Y. Kung¹

Institute of Electrical Engineering, Da-Yeh University, Chang-Hwa 515, Taiwan, ROC

^{*}Phone: +886-4-8528469 ext.2174, Fax: +886-4-8521904, E-mail: dsw@mail.dyu.edu.tw

National Chung Hsing University, Taichung 402, Taiwan, ROC

1. Introduction

Because of the high symmetry of cubic GaN (c-GaN) structure, it is theoretically predicted to have several advantages over hexagonal-GaN (h-GaN). From the viewpoint of device application, an optical cavity of laser diode is easily formed by cleavage and electrodes can be formed in the vertical configuration. In most of the previous studies, c-GaN was grown on the GaAs substrate only [1,2]. However, the GaAs surface often exhibits hollows during the high growth temperatures of GaN [3]. The occurrence of hollows is considered to be the desorption of As atoms from the GaAs surface. This situation is also similar for the GaP substrate. Note that GaP has superior thermal stability than GaAs. Besides, the lattice mismatch and the difference of thermal expansion coefficients between GaP and GaN are smaller as compared with those between GaAs and GaN [3]. In this work, GaN epilayers were grown on (001) GaP substrates by MOCVD using the three-step growth method, which includes the growth of the GaN buffer, interlayer and high-temperature epilayer. The process proposed was confirmed to be effective to restrict desorption of the P atoms and the characteristics of the as-grown GaN epilayer will be discussed.

2. Experimental

The GaN epilayers were grown on (001) GaP substrate by MOCVD using TMGa and NH₃ as the group III/V sources. After degreasing and etching, the GaP substrate was thermally annealed in H₂ ambient at 550°C for 10 min to remove the surface oxide. A 25-nm-thick GaN buffer layer was grown at 515°C under a V/III ratio of 40000 (1st step). Following the nucleation step, a GaN interlayer was then grown at temperatures (700°C–850°C) under a V/III ratio of 12500 (2nd step). Finally the high-temperature GaN epilayer was grown at 900°C under a V/III ratio of 12500 (3rd step).

3. Results and Discussion

It was found that the growth temperature of the GaN interlayer (2nd step) plays an important role in determining the overall quality. The morphology and crystalline properties of the GaN interlayers (1 μm in thickness) grown at various temperatures were shown in Figs. 1 and 2, respectively. At lower (≤700°C) or higher (≥800°C) growth temperatures, the epilayer exhibits h-GaN. A mixed phase of c-GaN and h-GaN is obtained at 750°C. The small islands shown in Fig. 1(a) could be due to the lower growth temperature (700°C) and yielded poor crystalline quality. The GaN interlayers grown at 800 and 850°C show irregular quadrilateral grains and rough surface. It can be interpreted by the fact that the GaP substrate is

degraded by the high growth temperature due to desorption of P atoms, resulting in a rough surface for the subsequent GaN interlayer growth. To further optimize the growth parameters, the morphology and x-ray properties of the GaN interlayer with various thicknesses grown at 750°C were analyzed and shown in Figs. 3 and 4, respectively. As the interlayer thickness increased, the grain shape changed from square to rectangle firstly and then the direction of the rectangle grain was crossed slightly. The direction of the rectangle grain shown in Fig. 3 (b) was parallel to the <110> direction and could be affected by the composition of hexagonal component in the interlayer. The trend correlates well with the x-ray measurement result (Fig. 4), where the cubic component is decreased from 95 to 25% as the GaN interlayer thickness increases from 0.2 to 0.6 μm.

From the above results, it is hardly to obtain good-quality of GaN on GaP by MOCVD using the conventional two-step method. Thus a three-step growth method was performed. After the initial nucleation, a GaN interlayer (0.2 μm in thickness) was grown at 750°C followed by a high-temperature growth at 900°C. The morphology and crystalline properties of the GaN epilayers with various thicknesses were analyzed and shown in Figs. 5 and 6, respectively. The smooth surface morphology shown in Fig. 5 (a) could be due to the existence of the GaN interlayer, which can protect the GaP surface at high temperatures. As the GaN epilayer thickness increased, the surface of the GaN epilayer became rougher. The coalescent direction shown in Fig. 5 was parallel to the <110> direction. The surface roughness and the coalescent direction could be affected by composition of the hexagonal component in the GaN epilayer. The trend correlates well with the x-ray measurement result (Fig. 6), where the cubic component is decreased from 68 to 34% as the GaN epilayer thickness increases from 0.6 to 1.1 μm.

Fig. 7 reveals the optical property of the GaN epilayer (0.6 μm in thickness) by MOCVD using the three-step growth method. The photoluminescence (PL) spectrum was measured at 77K and 300K with a He-Cd laser as the excitation source. A sharp near-band-edge emission peak at 367nm with a FWHM of 28 meV was observed at 77K. In addition, a broad emission was detected at longer wavelengths peaking at 486 and 496 nm at 77K. The origin of this broad emission is still controversial. It is believed to result from the autodoping of the GaP substrate.

4. Summary

A mirror GaN epilayer was grown on (001) GaP

by MOCVD using the three-step growth method. It was demonstrated that the GaN interlayer could efficiently restrict the P atoms desorption from the GaP surface, which is an essential step for the subsequent growth at high temperature (900°C). The optical quality was confirmed by the 77-K PL spectrum, where a strong near-band-edge emission at 367 nm with a FWHM of 28 meV was observed.

References

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- [2] A. Nakadaira, J. Electron. Mater. 26 (1997) 320.
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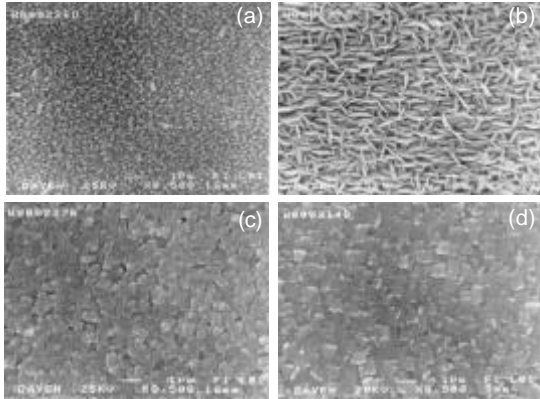


Fig. 1. SEM micrographs of the 2nd step GaN interlayers (1 μm thick) grown on GaN/ GaP(001) substrates at (a) 700, (b) 750, (c) 800 and (d) 850°C. The GaN buffer layers were grown at 515°C with a thickness of 25 nm.

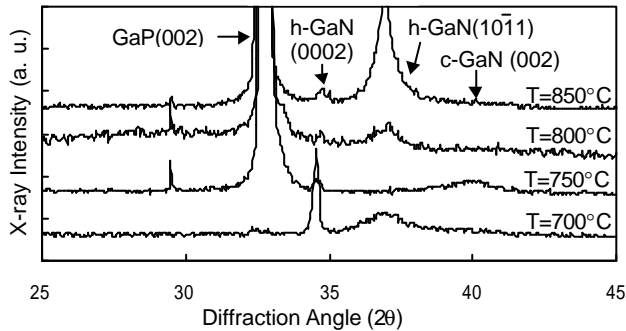


Fig. 2. X-ray diffraction scans of the GaN interlayers grown at various temperatures as described in Fig. 1.

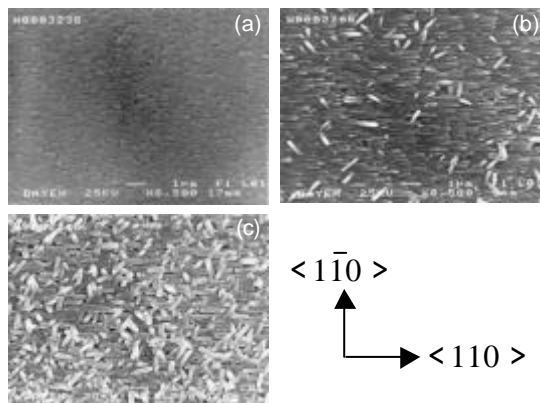


Fig. 3. SEM micrographs of GaN interlayers grown at 750°C with (a) 0.2, (b) 0.3 and (c) 0.6 μm thickness.

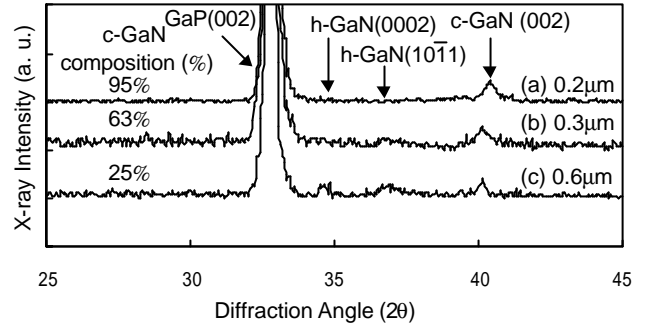


Fig. 4. X-ray diffraction scans of GaN interlayers grown at 750°C with (a) 0.2, (b) 0.3 and (c) 0.6 μm thickness.

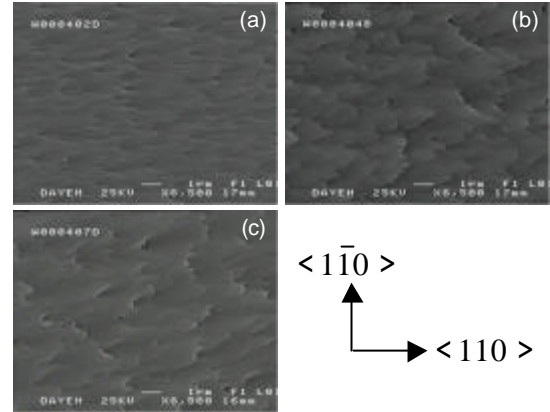


Fig. 5. SEM micrographs of GaN epilayer grown by three-step growth method (3rd step temperature: 900°C) with (a) 0.6, (b) 0.87 and (c) 1.1 μm thickness.

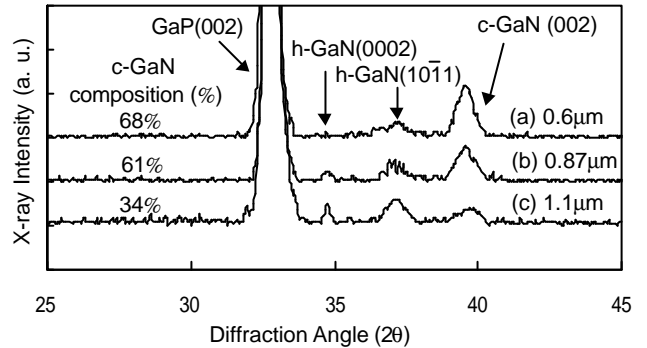


Fig. 6. X-ray diffraction scans of GaN epilayer grown by three-step growth method (3rd step temperature: 900°C) with (a) 0.6, (b) 0.87 and (c) 1.1 μm thickness.

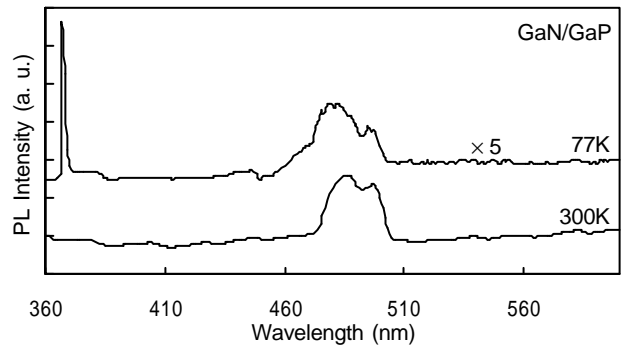


Fig. 7. 77- and 300-K photoluminescence spectrum of the 0.6-μm-thick GaN epilayer grown by three-step growth method (3rd step temperature: 900°C).